Lesson 4
Explain/ Elaborate

Drug Abuse and Addiction

Photo: Corel

At a Glance

Overview
Students will examine data from animal experiments. Through this activity, a card game, and a case study, students learn that although the initial decision to take drugs of abuse is voluntary, continued use may lead to addiction, which is the continued compulsive abuse of drugs in spite of adverse consequences. Students then watch a CD-ROM mini-documentary to learn how drugs cause long-term changes in the brain.

Major Concept
Addiction is a brain disease.

Objectives
By the end of these activities, the students will

- understand that drug abuse initially is a voluntary behavior,
- be able to define drug addiction as the continued compulsive drug abuse in the presence of adverse health or social consequences,
- understand that drug abuse and addiction are associated with long-term physical and functional changes in the brain, and
- recognize that addiction is influenced by the social and behavioral context of drug use.

Basic Science–Health Connection
Drug addiction is a complex brain disease. Preventing drug abuse and addiction and treating the disease effectively requires understanding the biological, genetic, social, psychological, and environmental factors that predispose individuals to drug addiction.

Background Information

Individuals make choices to begin using drugs. Some people begin using drugs to relieve a medical condition and then continue to use the drugs after the medical need is over. Children who are depressed or who have a psychiatric disorder sometimes begin using illicit drugs to self-medicate. Other people begin taking drugs to feel pleasure, to escape the pressures of life, or to alter their view of reality. This voluntary initiation into the world of addictive drugs has strongly influenced society's view of drug abuse, drug addiction, and its treatment.

When does drug abuse become drug addiction? No one becomes addicted with the first use of a drug. Drug abuse and drug addiction can be thought of as points along a continuum. Any use of a mind-altering drug or the inappropriate use of medication (either prescription or over-the-counter drugs) is **drug abuse**, but the point when drug abuse becomes drug addiction is less clear. Different drug abusers may reach the point of addiction at different stages. Scientists continue to investigate the factors that cause the switch between the two points.

Figure 4.1: The continuum of drug abuse and addiction.

Currently, **drug addiction** is defined as the continued compulsive use of drugs in spite of adverse health or social consequences.[1] Drug addicts have lost control of their drug use. Individuals who are addicted to drugs often become isolated from family or friends, have difficulty at work or school, and become involved with crime and the criminal justice system. For addicts, continuing their drug habit becomes their primary focus in life.

Certain drugs, including opiates and alcohol, cause strong physical reactions in the body when drug use stops. When a heroin addict stops taking heroin, he or she can experience a variety of symptoms ranging from watery eyes and a runny nose to irritability and loss of appetite and then diarrhea, shivering, sweating, abdominal cramps, increased sensitivity to pain, and sleep problems.[2] In general, withdrawal from heroin makes the abuser feel miserable. Withdrawal from other drugs, such as cocaine and amphetamines, does not lead to strong physical reactions. For most drugs, physical withdrawal symptoms can usually be controlled effectively with medications. Even though withdrawal from some drugs does not cause the abuser to have physical reactions, stopping drug use is difficult because of the changes the drugs have caused in the brain. Once the drugs stop, the abuser will have **cravings**, or intense desire for the

drugs.[3] Craving arises from the brain's need to maintain a state of homeostasis that now includes the presence of the drug. A person may experience cravings at any stage of drug abuse or addiction, even early in the experimentation phase of drug abuse. Cravings have a physical basis in the brain. Using PET imaging, scientists have shown that just seeing images of drug paraphernalia can stimulate the amygdala (part of the brain that controls memory) in drug addicts.[4]

Drugs of addiction do not merely cause short-term changes in an individual's cognitive skill and behavior. A drug "high" lasts a short time, ranging from less than an hour to twelve hours depending on the drug and dose. The changes in the brain that result from continued drug use, however, can last a long time. Scientists believe that some of these changes disappear when drug use stops; some disappear within a short time after drug use stops, and other changes are potentially permanent. One of the first changes in the brain that occurs in response to repeated drug abuse is tolerance. **Tolerance** develops when a person needs increasing doses of a drug to achieve the same "high" or "rush" that previously resulted from a lower dose of the drug. Two primary mechanisms underlie the development of tolerance.[3] First, the body may become more efficient at metabolizing the drug thereby reducing the amount that enters the bloodstream. Second, the cells of the body and brain may become more resistant to the effect of the drug. For example, after continued cocaine use, neurons decrease the number of dopamine receptors, which results in decreasing cocaine's stimulatory effect. Opiates, on the other hand, do not cause a change in the number of receptors. Instead the opiate receptors become less efficient in activating the second messenger system thus reducing the effects of the opiates.

Drugs can cause other long-term changes in the anatomy and physiology of the brain's neurons. Alcohol, methamphetamine, and MDMA (Ecstasy) can kill neurons.[3] Unlike other types of cells in the body, neurons in many parts of the brain have little or no capability to regenerate. (Recent studies have shown that the adult human brain can generate new neurons in the hippocampus, a part of the brain important for learning and memory.[5] Other parts of the brain do not show this ability.) Alcohol kills neurons in the part of the brain that helps create new memories. If those neurons die, the capability for learning decreases. Methamphetamine kills dopamine-containing neurons in animals and possibly in humans as well.[6] MDMA kills neurons that produce another neurotransmitter called serotonin.[7] In addition to neurotoxic effects, drugs can significantly alter the activity of the brain. PET scans of cocaine addicts show that the metabolism of glucose, the primary fuel for cells, is drastically reduced in the brain, and that this decrease in metabolism can last for many months following cessation of drug abuse.[8]

In addition to the functional and anatomical changes in the brain, drug abuse puts addicts at higher risk for other health problems. For example, inhalant abuse can lead to disruption of heart rhythms and snorting cocaine can lead to ulcerations in the mucous membranes of the nose. In addition, drug addicts are at increased risk of contracting HIV or AIDS through shared needles. Similarly,

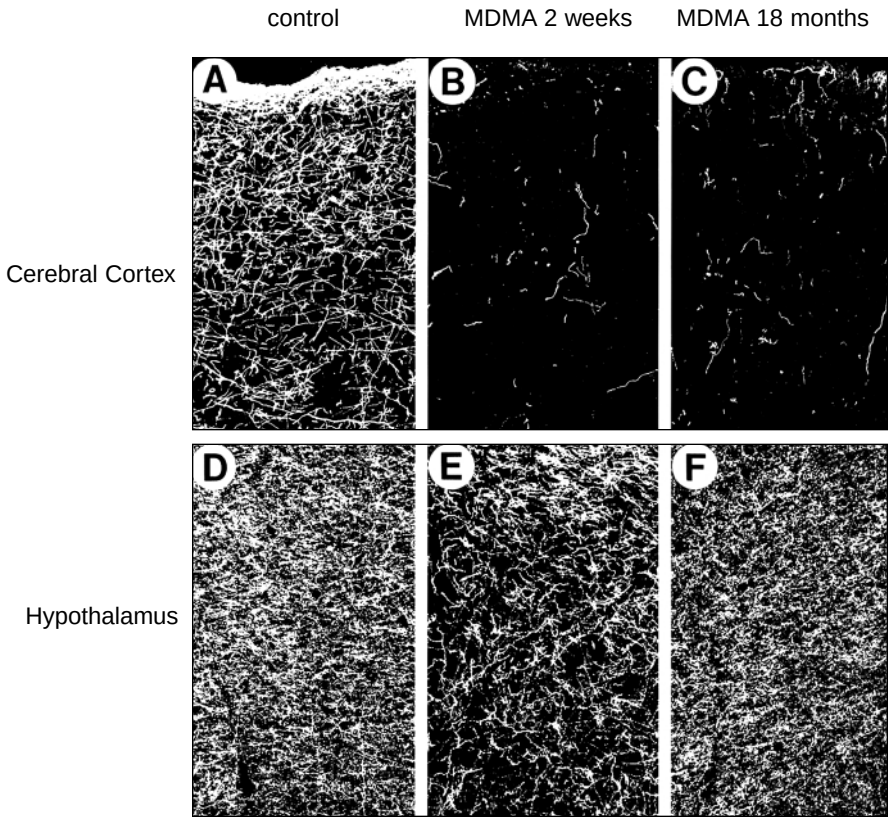

Figure 4.2. Photographs of serotonin axons in the cerebral cortex labeled with a fluorescent marker. The number of serotonin-labeled axons is dramatically reduced in the cerebral cortex at 2 weeks (B) and 18 months (C) after the last drug use. The brain of the control animal that did not receive MDMA (A) shows the dense network of labeled axons. Images E and F show changes caused by MDMA use on a different brain region, the hypothalamus. The control showing the hypothalamus in the absence of MDMA is shown in D. Photographs courtesy of G.A. Ricaurte, with the permission of the *Journal of Neuroscience.*

hepatitis B and hepatitis C are much more common among drug addicts than the general population. Tuberculosis is another concern. Drug abuse and addiction also are contributing factors in motor vehicle accidents.

Genetic, Behavioral, and Environmental Influences on Drug Addiction

Drug addiction is not simply continuous drug abuse. Many more individuals will try an addictive drug than will become addicted. Most people know of situations in which two people use the same amount of alcohol or tobacco, but have very different responses to them. Environmental, social, behavioral, and genetic factors also contribute to the development of drug addiction. Stress can increase the susceptibility to addiction.

Scientists continue to investigate the factors that place one individual at greater risk of becoming addicted than another individual with a similar pattern of drug use. Individuals who have developed strong coping skills to deal with life's pressures have less risk of becoming addicted to drugs. The younger a person is when he or she begins using drugs, the more likely he or she is to become addicted. This may be true because younger individuals have not developed the

Medical Uses of Addictive Drugs

Drugs of abuse can cause long-term impairment in brain function. But, are there times when addictive drugs can be beneficial to human health? The first drug that may come to mind is morphine. During the Civil War, doctors gave morphine to wounded soldiers to relieve the pain of brutal injuries. Doctors didn't realize how addictive injected morphine was until many soldiers became addicted to the drug.[2] Morphine addiction became known as "soldiers' disease." Today, morphine is a valuable medicine to relieve pain when administered with the appropriate medical supervision. Patients in hospitals receive morphine to ease their pain after surgery, and during cancer and burn treatment. Very few of these patients become addicted to morphine even though they may take it for extended periods of time.[9]

Another drug that has received considerable attention for its potential benefits is marijuana. Television and newspaper reports periodically present stories on the use of marijuana by terminal cancer or AIDS patients to ease their discomfort and pain. Scientists continue to investigate the potential benefits of marijuana because the studies conducted so far have been limited in focus or quality. In addition to causing changes in the brain, marijuana smoke contains many chemicals, some of which are carcinogenic to lung tissue.[10] Therefore, if it is to be an effective medicine, marijuana must be available in a safer form. The active ingredient in marijuana, tetrahydrocannabinol (THC), is currently available by prescription as an oral medication. This form of the drug is likely to be neither as addictive, nor as effective, as the smoked form because the drug breaks down in the digestive tract and takes longer to get into the bloodstream. Additional studies are needed to develop a form of THC that may be inhaled. The availability of an inhalable form of THC would stimulate research into its use as a medicine. However, other obstacles also exist. Are other medications safer and more effective than THC without causing the impairment of brain function and other health problems? If so, use of THC would be difficult to justify. In March 1999, the Institute of Medicine issued a report assessing what scientific studies have shown about marijuana's potential medicinal qualities.[10, 11] That report concluded that smoking marijuana may lead to significant health problems and that additional studies are necessary before the medical use of marijuana can be justified. The National Institutes of Health (NIH) does support quality, controlled research studies to investigate whether marijuana, and more specifically THC, may have potential beneficial effects as a medicine. Until those studies can be completed to determine if there is a scientific basis for medicinal claims, NIH believes marijuana should be viewed as an addictive drug that causes brain impairment, not as a medicine.

coping skills necessary to deal with life's ups and downs. Furthermore, the earlier drug use begins, the less likely treatment is to be effective. In addition, genetic factors probably influence who engages in higher-risk behaviors.

The context in which a person uses an addictive drug is important. For example, some cancer patients take relatively large doses of morphine for extended periods to control pain without becoming addicted. In one study of 12,000 patients who were given opioids (primarily morphine) for acute pain, only four individuals became addicted to the drugs. In another study of 38 chronic pain patients, most of whom received opioids for four to seven years, only two patients became addicted, and both had a history of drug abuse.[9] It is thought that addiction is rare in these pain patients because, unlike the stereotypical street addict, they are not taking the drugs to get "high" and to escape life, rather they take the drugs so they can get on with life. The drugs ease their pain and improve their quality of life.

In the 1970s, news media reported the use of marijuana and heroin by soldiers who were serving in Vietnam. Combat stress, the easy availability of drugs, and the relaxation of taboos against drug use at the time all contributed to the problem. While many soldiers did have drug problems while in Vietnam, 95 percent who were addicted to narcotics have had no addiction problems since they returned to the United States.[13]

Scientists continue to learn more about how genetic factors influence drug abuse and addiction. Heredity influences whether an individual has positive or negative sensations after smoking marijuana. One study demonstrated that identical male twins were more likely than non-identical male twins to report similar responses to marijuana use, indicating a genetic basis for their sensations.

Animals as Research Models

Why do scientists study the brains of non-human animals? Scientists use animals in research studies because the use of humans is either impossible or unethical. For example, when scientists investigate the effects of drugs of abuse on brain function, either the question they are asking cannot be answered in a living human or it would be inappropriate to give drugs to them.

The use of animals as subjects in scientific research has contributed to many important advances in scientific and medical knowledge. Scientists must analyze the goals of their experiments in order to select an animal species that is appropriate. Scientists often use fruit flies (*Drosophila melanogaster*) when they want to learn more about genetics. However, fruit flies are not a very good model if a scientist is investigating muscle physiology; a mouse may be a

Guidelines for the Use of Animals in Scientific Research

Scientists who use animals as research subjects must abide by federal policies that govern the use and care of vertebrate animals in research. The Public Health Service established a policy that dictates specific requirements for animal care and use in research. This policy conforms to the Health Research Extension Act of 1985 (Public Law 99-158) and applies to all research, research training, biological testing, and other activities that involve animals.[14] The principles for using and caring for vertebrate animals in research and testing are as follows:

- The transportation, care, and use of animals should be in accordance with the Animal Welfare Act and other applicable Federal laws, guidelines, and policies.
- Procedures involving animals should be designed with consideration of their relevance to human or animal health, the advancement of knowledge, or the good of society.
- The animals selected should be of an appropriate species and quality and the minimum number required to obtain valid results. Methods such as mathematical models, computer simulation, and *in vitro* biological systems should be considered.
- Procedures should minimize discomfort, distress, and pain to the animals.
- Procedures that may cause more than momentary or slight pain should be performed with appropriate sedation, analgesia, or anesthesia.
- Animals that would suffer severe or chronic pain or distress that cannot be relieved should be painlessly killed.
- The living conditions of animals should be appropriate for the species. The housing, feeding, and care of animals must be directed by a veterinarian or a trained, experienced scientist.
- Investigators who work with animals must be appropriately qualified and trained for conducting procedures on living animals.
- Exceptions to any of these principles must be reviewed and approved by an appropriate committee prior to the procedure.
- An Institutional Animal Care and Use Committee (IACUC) oversees all animal use in each institution where animal research is conducted. The IACUC must give approval for the research plan and species to be used. IACUCs include both scientists and nonscientists from outside the institution. Nonscientists are often representatives of humane organizations.

better model for those experiments. Although scientists strive to develop non-animal models for research, these models often do not duplicate the complex animal or human body. Continued progress toward a more complete understanding of human and animal health depends on the use of living animals.

In Advance

CD-ROM Activities	
Activity Number	**CD-ROM**
Activity 1	no
Activity 2	no
Activity 3	no
Activity 4	no
Activity 5	yes

Photocopies	
For the class	**For each student**
1 transparency of Master 4.4, *Playing the Game* 1 transparency of Master 4.5, *Who Is Addicted?*	1 copy of Master 4.1, *Data for Rat Self-administration Experiment* 1 copy of Master 4.2, *Worksheet for Rat Experiment Data* 1 copy of Master 4.3, *Evaluating the Experiment* 1 copy of Master 4.6, *Long-term Effects of Drugs on the Brain* (only if using the non-CD-ROM activity)

Materials	
Activity 1	none
Activity 2	colored pencils overhead projector transparency
Activity 3	playing cards (one deck for each group of 3 students; see Preparation section) overhead projector
Activity 4	overhead projector
Activity 5	computers

Preparation

Gather decks of playing cards for use in Activity 3. Each group of 3 students can share one deck of cards. Separate the face cards (jacks, queens, and kings) and place them in one pile. Place the aces and number cards in another pile.

Arrange for students to have access to computers for viewing the CD-ROM mini-documentary in Activity 5.

Procedure

Content Standard F: An individual's mood and behavior may be modified by substances.

ACTIVITY 1: HOW DOES DRUG ABUSE BEGIN?

1. **Begin the activity by holding a class discussion. Ask students "What is a drug?" Write their answers on the chalkboard or on an overhead transparency. Give students the opportunity to present differing views.**

   Students will respond with a variety of answers. Some will give examples of illegal drugs, such as marijuana or cocaine, others may give the names of prescription medications. If so, prompt students to think about a definition for the word *drug*. Some students will describe a drug either as an illegal substance that harms a person's health or as a chemical that a person takes to treat a disease or illness. At this point, based on students' knowledge, both definitions are correct.

   Several terms will be introduced in this lesson. It is **very important** to use these terms according to the definitions provided.

2. **Write the following definitions for *drug* and *medication* on the board or transparency and inform students that, for this discussion, you will use the terms according to the following definitions.**

   - **A *medication* is a drug that is used to treat an illness or disease according to established medical guidelines.**
   - **A *drug* is a chemical compound or substance that can alter the structure and function of the body. Psychoactive drugs affect the function of the brain, and some of these may be illegal to use and possess.**

3. **If the students didn't do this in the previous question, ask them to consider examples for both medications and drugs. List each response in the proper category as a medication or a drug.**

   According to these definitions, all medications are drugs, but not all drugs are medications. This unit uses the word "drug" to refer to psychoactive drugs, or drugs of abuse. Drug abuse refers to the use of illicit drugs or to the inappropriate use of a legal drug, such as alcohol or nicotine.

   Societal and political factors sometimes influence into which category a substance falls. Alcohol and nicotine (tobacco) are drugs that are illegal to use and possess if the individual is below legal age, but not for adults to possess and use responsibly. Also, inhalants (paints, glues, and sprays, for example) are not illegal to possess when they are used for their intended purposes. However, they are drugs when used improperly to alter brain function.

Some students will raise the idea that medications can also be drugs if they are used inappropriately. For example, overuse of a prescription medication, such as a sedative, is inappropriate and could be considered a drug in that case. Alternatively, students may indicate that morphine is an illegal drug when used without medical supervision, but is a valuable medicine when used appropriately in a hospital, or at home, to relieve pain associated with various diseases. Students may also propose that marijuana can be a medication to relieve the pain that accompanies various diseases. (In some states, marijuana is legal as a medication, but is illegal according to Federal law.) If students bring this up, point out to them that scientists need to continue studying marijuana to determine if it may be effective as a medicine. Marijuana contains hundreds of chemical compounds; the effects of most of these compounds in the body are unknown. Marijuana also poses many problems outside of the brain, such as cancer. Use this as an opportunity to inform students that scientific research is being done to determine if marijuana is more effective than other medicines (see the Background Information section).

4. **Ask students to respond to the question: Why do people start abusing drugs?**

   Students may provide a wide range of answers to this question including peer pressure, experimentation, boredom, or fun. Some students may also respond that people take drugs to escape from life's pressures.

ACTIVITY 2: DRUG ABUSE IS VOLUNTARY; ADDICTION IS COMPULSIVE

1. **For this activity, students will work in groups of four. Prior to having students divide into their small groups, set the stage for the activity. Tell students they will be analyzing data from experiments using rats. For the experiments, rats were placed in individual cages with two levers that the rat could press. If the rat pressed the food lever, a pellet of food was released. If the stimulus lever was pressed, the rat received an injection or an electrical stimulus.**

   Students may ask what substance was injected in response to the press of the stimulus lever. Tell students that the answer to that question will be revealed during the activity.

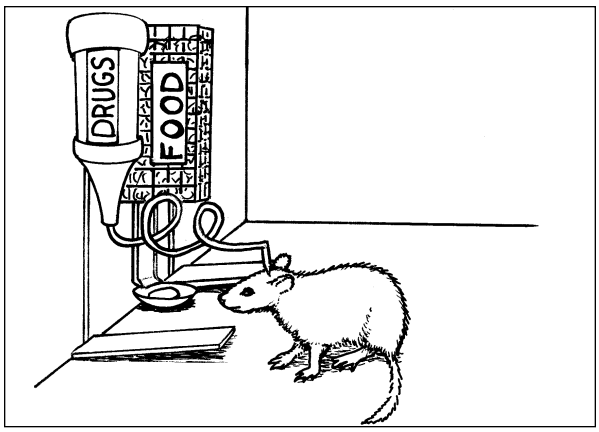

Figure 4.3 Diagram of a rat in a cage during a drug self-administration experiment.

Content Standard A: Mathematics is essential in scientific inquiry.
Content Standard A: Scientists rely on technology to enhance the gathering and manipulation of data.
Content Standard C: Organisms have behavioral responses to internal changes and to external stimuli.
Content Standard F: An individual's mood and behavior may be modified by substances.

2. **Give each student a copy of Masters 4.1, *Data for Rat Self-administration Experiments*, and 4.2, *Worksheet for Rat Experiment Data*. Each student will graph on Master 4.2 the data for only one of the rats. Instruct the teams to decide which member will graph the data for rat A, B, C, and D. The students will plot the total number of times that the rat presses the stimulus lever vs. time and the total number of times that the rat presses the food lever vs. time.**

   The graph of the data for each rat will have two lines, one for the stimulus lever and one for the food lever. Students can use a different color of pencil for plotting each set of data, or they can use a solid line and a dashed line to distinguish between the two graph lines.

3. **After students have completed their graphs, give each student a copy of Master 4.3, *Evaluating the Experiment*. Each student should share his or her graph with the other members of the group. Group members then discuss the similarities and differences among the rats' responses and answer the questions on Master 4.3.**

4. **When the groups are finished answering the questions, hold a class discussion to ensure that each group has come to the appropriate conclusions.**

SAMPLE ANSWERS TO QUESTIONS ON MASTER 4.3

Question 1. Why do the rats press a lever the first time?

The rats initially press a lever while they are exploring the cage. The rat may even press the lever by accident. Whether the rat presses the food lever or the stimulus lever first is usually random.

Question 2. Compare the lever-pressing behaviors of the four different rats. Which rat pressed the stimulus lever the most? Which one pressed the stimulus lever the least? Which rat pressed the food lever the most? Which one pressed the food lever the least?

Rats A and C pressed the stimulus lever about the same number of times and many more times than either Rat B or Rat D. Rats B and D did not press the stimulus lever very many times, but they pressed the food lever more times than Rats A and C did. Overall, Rats A and C behaved similarly and Rats B and D behaved similarly.

Question 3. Rat A was injected with cocaine each time it pressed the stimulus lever. Can you use this fact to explain why Rat A behaved the way it did?

The cocaine activated the reward system in the brain and caused the rat to continue its stimulus lever-pressing behavior. If necessary, remind students that the reward system is the part of the brain stimulated by drugs to cause feelings of pleasure.

Question 4. Based on the data you analyzed, do you think Rat B was injected with cocaine when it pressed the stimulus lever? From what you have learned so far in this unit, do you think Rat B was injected with a different addictive drug when it pressed the stimulus lever? Why?

It appears that Rat B was not injected with cocaine when it pressed the stimulus lever because its behavior was very different from Rat A. If Rat B was injected with cocaine or another addictive drug, it should display behavior similar to Rat A.

(Rat B actually received a saline injection when it pressed the stimulus lever.)

Question 5. Do you think Rat C received cocaine when it pressed the stimulus lever? Why?

It is possible that Rat C received cocaine when it pressed the stimulus lever because its behavior was very similar to that of Rat A. However, you cannot be sure if it was cocaine.

Question 6. Rat C did not receive an injection of cocaine when it pressed the stimulus lever. When Rat C pressed the stimulus lever, it received a mild electrical stimulation in the brain. Based on what you have learned, can you predict what part of the brain was stimulated?

The reward system (ventral tegmental area or nucleus accumbens) is the part of the brain stimulated. Stimulation in that area of the brain caused the rat to continue pressing the stimulus lever.

Question 7. Rat D also received a mild electrical stimulation in the brain when it pressed the stimulus lever. Do you think the same part of the brain was stimulated in Rat D as was stimulated in Rat C? Why?

Rat D did not receive an electrical stimulation in the same part of the brain that was stimulated in Rat C. If the same part of the brain, the reward system, was stimulated, Rat D should behave similarly to Rat C.

(Rat D received an electrical shock in the cerebellum, which is not part of the reward pathway.)

Question 8. Why did Rats A and C press the stimulus lever more than the food lever?

Rats A and C received a greater "reward" when they pressed the stimulus lever than they did when they pressed the food lever.

Question 9. Why did Rats B and D press the food lever more than the stimulus lever?

Rats B and D received greater "reward" when they pressed the food lever than they did when they pressed the stimulus lever.

Question 10. Why did the scientists who conducted this experiment include Rats B, C, and D in this experiment? How did the data from those rats help scientists understand more about how cocaine acts in the brain?

Rats B, C, and D were used as controls in this experiment. Rat B received a saline injection after pressing the stimulus lever. (The cocaine that Rat A received was dissolved in a saline solution.) Because Rat B's behavior

differed from Rat A's behavior, this suggests that the cocaine that Rat A received caused the frequent stimulus lever-pressing behavior. Because both rats had a canula inserted to deliver the solution, the process of inserting the canula is not sufficient to cause Rat A's behavior.

The data from Rat C reveal that electrical stimulation of the VTA elicits behavior similar to that caused by cocaine injection. Because cocaine is known to act on neurons in the VTA, these data reinforce the findings from Rat A that the cocaine acting on the VTA neurons causes the frequent stimulus lever-pressing behavior.

Rat D received electrical stimulation in the cerebellum after pressing the stimulus lever. The cerebellum is not part of the reward system. These data show that stimulation to a discrete brain area, the reward system, causes Rat C's behavior. Inserting the electrode into other areas of the brain is not sufficient to elicit the rapid stimulus lever-pressing behavior observed in Rat C.

Question 11. Do you think that Rats A and C will stop pressing the stimulus lever if they continue to receive the same stimulation each time they press it? Why?

Based on the data, it does not seem likely that Rats A and C would stop pressing the stimulus lever because the number of times it is pressed continues to increase within each five minute period. Students may notice that Rat A pressed the stimulus lever more times during the last five-minute period of the experiment than it did during the first five-minute period

Question 12. Based on what you learned from these data, what might this investigation tell you about drug use by humans? Explain your view.

The data from the rat experiment show that the use of addictive drugs is reinforcing. Rats who are given cocaine want more cocaine. Because rats are mammals just as humans are and many of their organs function in ways similar to those in humans, the data suggest that drug use in humans is likely to be reinforcing as well: humans who take drugs will probably want to continue taking drugs.

5. Have students consider the question, Why do humans continue to abuse drugs?

Drug addicts continue to take drugs in spite of negative consequences. They know that their family, social, or career interactions are disrupted by their drug abuse, but they cannot stop. Drug-taking becomes *compulsive.* Rats A and C became conditioned to the activation of the reward system by the administration of cocaine or electrictrical stimulation in the VTA in response to a lever press. Those rats continued to press the stimulus bar in their cages and ignored the food lever. The cocaine or electrical stimulation in the VTA was a bigger reward for the rats than was the food. In humans, drugs cause a compulsive need for more drugs.

6. Write the following definition of addiction on the chalkboard or overhead transparency.

- ***Addiction* is the continued compulsive use of drugs in spite of adverse health or social consequences.**

7. Ask students to consider what they learned from the data concerning the continued use of cocaine by Rat A and the continued stimulation of the reward pathway in Rat C. Did Rat A and Rat C experience any adverse effects from their treatments? What adverse consequences do human drug addicts experience?

Although it is not appropriate to refer to the rats as addicted to cocaine, those rats would have experienced adverse effects if the experiment continued for a long time. If the experiments continued and the rats continued to push only the stimulus lever, the lack of food and water would lead to adverse health consequences. If the scientists did not stop the experiment, the rats would have continued to press the stimulus lever until they died from a cocaine overdose.

Human addicts are most concerned with their next drug use. Because of this, they often eat little or poorly and consequently suffer the adverse health consequences of poor nutrition.

8. Ask students to consider the distinction between drug abuse and drug addiction in humans.

- **When does abuse become addiction?**
- **What causes abuse to become addiction?**
- **Does the change from abuse to addiction occur at the same level (amount of drug taken, duration of drug abuse) of drug abuse for different individuals?**

Students should be able to use the previously given definition of addiction and the results of the cocaine self-administration experiments with rats to differentiate between drug abuse and addiction. Abuse is voluntary; addiction is the compulsive, continued drug use in spite of adverse health or social consequences.

Scientists do not know what causes a drug abuser to become an addict. Continuing research is attempting to answer this question.

ACTIVITY 3: WHEN DOES ABUSE BECOME ADDICTION?

1. Divide the class into groups of 3 students. Give each group a deck of cards that have been divided into two piles. Tell the students that the small pile contains the face cards and the larger pile has the aces and number cards.

2. Display a transparency of Master 4.4, *Playing the Game*, showing the instructions for the game. Have students play through the game. Each student in the group will play individually, but the group members share the deck of cards.

Content Standard F: Personal choice concerning fitness and health involves multiple factors.

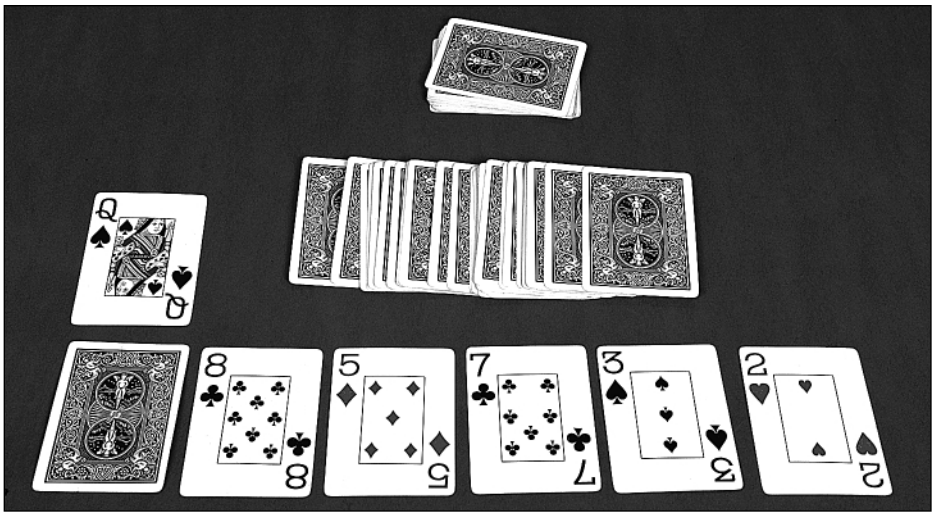

Figure 4.4: The arrangement of cards during the game.

3. **When all the groups have finished the game, discuss the game and the results of the game with them. The value of this activity lies in the discussion and questions that it may generate. The following sample questions can guide the discussion.**

   • **How many choice cards did each person pick?**

   Students will draw different numbers of cards before they decide to stop.

   • **How many people equaled or went over the value of the switch card?**

   Some students will decide to play it safe whereas other students will risk going over the switch value.

   • **How does this game relate to drug abuse and drug addiction?**

   This game relates to abuse and addiction in that each person who continues to abuse drugs will reach some point that, if surpassed, will change the person and the person's brain from a drug abuser to a drug addict. Each person has risk factors and each person can make choices about abusing drugs.

   • **What does the switch card mean in regard to drug addiction?**

   When a person abuses drugs, there is some point at which the person's brain changes and the individual becomes compulsive about using drugs despite negative consequences. Scientists do not know what factors control the "switch" between drug abuse and addiction.

   • **Is everyone's switch level the same?**

   In the card game, students choose one of three cards, each assigned an arbitrary value, as their *switch* card. In life, a person does not know when he or she will reach the point where drug abuse switches to drug addiction. For

some people, that change will occur earlier in their drug abuse while other people will abuse drugs extensively before they become addicted.

• **What does the risk card mean?**

The risk card symbolizes that there are factors that influence the outcome. An individual does not know what all the risks are or how great their influence is.

• **Is everyone's risk card the same?**

Different students will have different risk cards. In life, people who abuse drugs have different risks of becoming addicted.

• **Why is the risk card face down?**

The risk card is face down because a person does not know all of the risk factors that help determine if a person becomes addicted.

• **What factors influence a person's risk of becoming addicted to drugs?**

Many factors influence whether a person becomes addicted to drugs. Some of these include genetics, family influence, influence of friends, age at which drug abuse begins (a person who begins using drugs early in life is more likely to become addicted), context of drug use, and the development of coping skills.

• **What do the choice cards represent?**

Each choice card in this model represents an episode of drug use.

Students likely will try to assign meaning to the numbers on the choice cards. For example, they may equate a 2 with drinking a low alcohol beer and a 10 with heroin injection. These correlations are difficult to make with any accuracy. For example, a person may smoke a small amount of marijuana believing that it contains a low dose of THC. If that marijuana is of a potent strain that contains a high level of THC, the individual could receive a higher dose than if he or she smoked a larger dose of a less potent strain of marijuana.

Like most models, this one has imperfections. The discussion that this issue may generate among students can be valuable because it causes them to question drug abuse.

• **If a total score that equals or goes over the switch value indicates addiction, did anyone become addicted to drugs with the first drug use?**

The point values in the game have been assigned so that the player cannot reach the switch value after drawing one choice card. This correlates with addiction; no one becomes addicted with one episode of drug abuse.

Important note: This is true with the outcome of the game being *drug addiction* if the switch value is reached. This is not true if the designated outcome is *death* if the switch value is reached. A person can die from the first

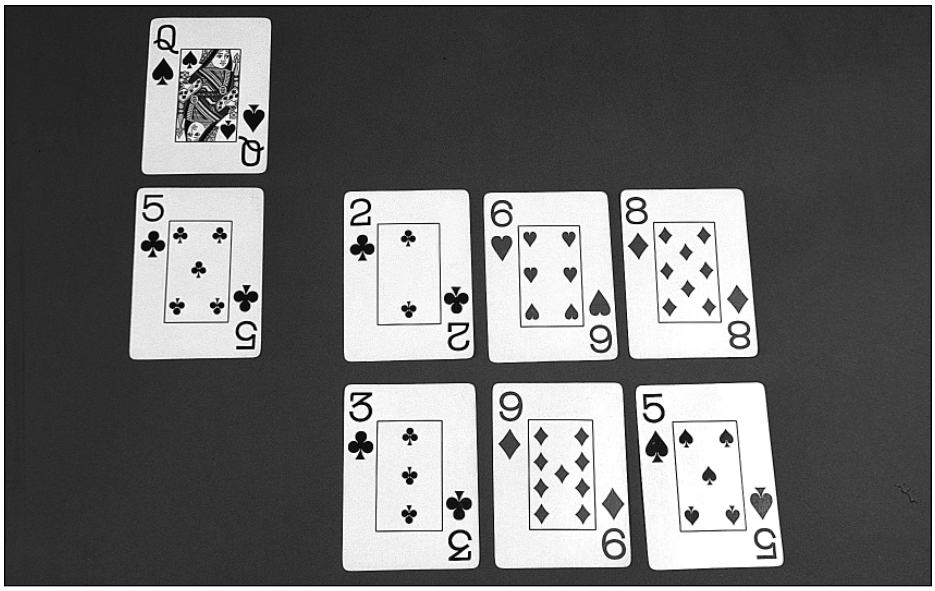

Figure 4.5: Sample card hand #1. The player had a moderate switch value (the switch card is a queen). The student elected to draw 6 choice cards totaling 33 points before finding out that the risk card had a value of 5. The 38-point total put the score over the switch value (35), signifying addiction.

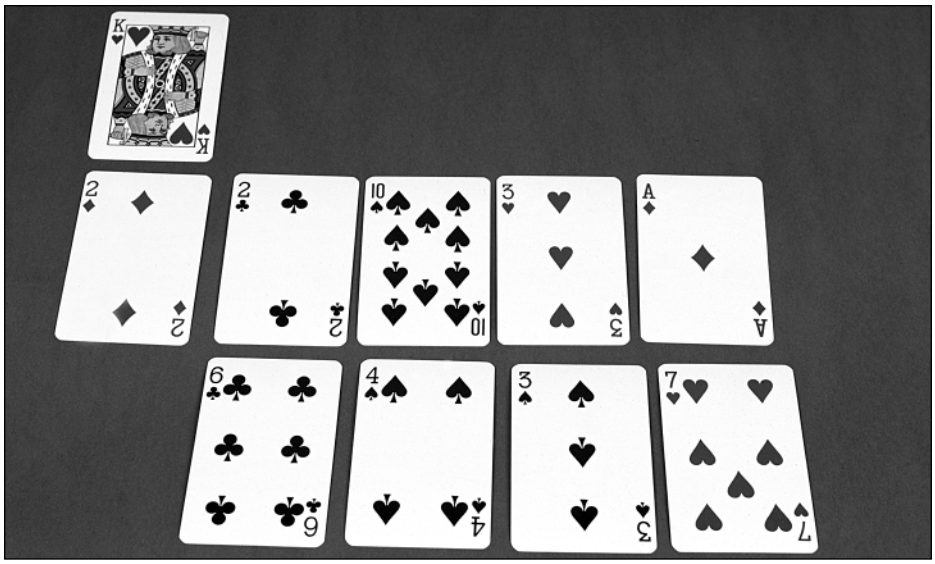

Figure 4.6: Sample card hand #2. The player had a higher switch card (king = 45 points) and elected to draw 8 choice cards totaling 36 points. Because the risk card was low (a 2), the 38-point total was still below the switch value, signifying drug abuse.

episode of drug abuse. After one use, drugs do not change the brain sufficiently to cause addiction. However, drugs can affect other body systems and cause them to fail. See Step #9 (on page 92) for a modification of the game to address this. Also, although a person does not become *addicted* to drugs after one use, one episode can cause some changes to start occurring in the brain. For example, one use of crack cocaine can cause the abuser to experience cravings for the drug.

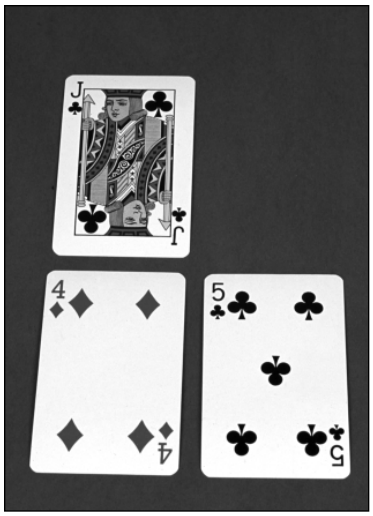

Figure 4.7: Sample card hand #3. The player elected to draw only one choice card, a 5, to ensure that the total of risk (which turned out to be a 4) and choice cards remained below the switch value of 25 points (jack = 25 points).

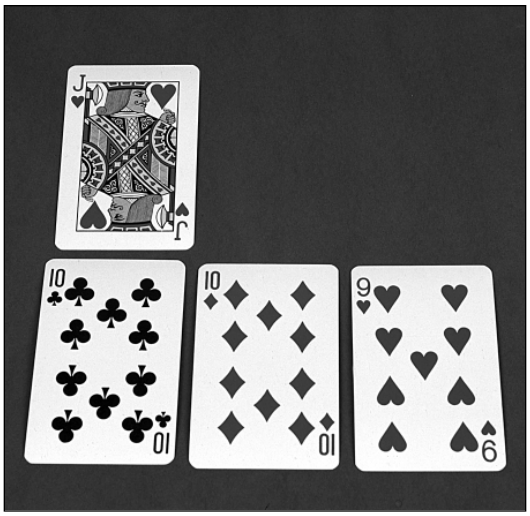

Figure 4.8: Sample card hand #4. The player drew a low switch card (a jack = 25 points) and a high risk card (a 10). Because the choice cards have high point values, the total of just two cards totaled more than the switch value, signifying drug addiction.

4. Have the students play the game again now that they can relate the game to the issues of drug abuse and drug addiction.

5. Ask students if they played the game any differently this time. Did they make different choices?

Some students will continue to risk drawing more choice cards and get closer to the switch value. Other students may elect not to draw any choice cards.

Some students might bring up questions relating to a hand containing a high switch card, a low risk card, and some low choice cards so that they can continue to draw more cards. Students may feel that this scenario would lead them to continue to experiment with drugs. You can respond by asking them what choices they would make if they drew a low switch card and a high risk card. (Perhaps the numbers on the cards are lower or higher than the assigned values. For example, what if the switch card had a value of 22 points and the risk card had a value of 12 points? Would this change the decision about drawing additional cards?) This scenario leads into the next step of the activity in which students consider that the switch point really is unknown.

6. **Discuss the idea of the switch card with students. Does anyone really know at what point in drug abuse the brain changes and the abuser becomes an addict? How could you modify the card game to account for this?**

   In life, a person does not know when he or she will reach the point at which drug abuse becomes drug addiction. To reflect this in the card game, students can play the game leaving the switch card face down.

7. **When the students play the game this time, they will not look at the switch card. Have them keep the switch card face down and continue the game as before.**

8. **Continue the discussion of the game and its relation to drug abuse and drug addiction.**

   The main points that students should learn through this activity are:

   - Drug abuse involves choice.
   - The point at which a person's brain is changed and drug abuse becomes drug addiction is different and unknown for each individual.
   - Everyone has risk factors.
   - A person does not become addicted to drugs after one episode of abuse.

9. **(optional) A person does not become addicted to drugs after one episode of abuse, but a person can die as a result of one episode of drug abuse. The drugs can act on other body systems with a lethal outcome. If you want to modify the game to add this scenario, insert the jokers into each pile of choice cards and have the students play the game a fourth time. If a student draws a joker, the game is over for that student.**

   If you decide to do this optional modification to the game, make sure that students understand that the joker does *not* indicate addiction. The joker would, perhaps, represent a batch of drugs that contain a lethal contaminant that would cause some body organ to fail and, therefore, cause the abuser to die. Another person, for example, takes a large enough dose of opiates to completely inhibit the neurons in the brain that control respiration; those neurons no longer stimulate the lungs to contract, causing death.

Content Standard C: An individual's mood and behavior may be modified by substances.
Content Standard F: Personal choice concerning fitness and health involves multiple factors.

ACTIVITY 4: ENVIRONMENTAL, BEHAVIORAL, AND SOCIAL INFLUENCES ON DRUG ABUSE AND ADDICTION

Note to teachers: This activity, as described in the following steps, is designed as a class discussion. An alternative approach is to have individual students write their answers to the questions and then discuss the questions as a class.

1. **Display a transparency of Master 4.5, *Who Is Addicted?*, showing only the top section (to the first horizontal line). Ask students to answer the question.**

Students may respond differently to the question about who is addicted to morphine. At this stage, any answer is acceptable if the student can explain the reasoning underlying his or her answer. Some students will say that Chris is addicted because of the higher dose of morphine being taken over a longer period of time. Some students will say Pat because this could be a larger dose than what Chris is taking (if Chris is at 50 mg per day). Students could also believe that both individuals are addicted because of their continued drug abuse. Conversely, students could respond that possibly neither one is addicted and more information is needed before a judgment could be made.

2. Reveal the next section on Master 4.5 (to the next horizontal line). Again have students answer the question and discuss the responses.

Students may respond in a variety of ways. Answers could involve aspects of genetics, dose, or even random chance.

3. Reveal the remaining section of Master 4.5 and have students read the case studies.

4. Discuss the cases with the class. Use the following questions to guide the discussion.

- **Why did these two individuals begin taking morphine and then continue to take morphine?**

Pat began abusing morphine basically for social reasons. Chris began taking morphine for medical reasons.

- **What are the differences in *how* Chris and Pat take morphine?**

Pat takes an injection of morphine one time each day. Chris also receives morphine through injection, but he receives a dose many times each day.

- **How may these differences have influenced whether addiction develops?**

Although Chris receives a higher total dose of morphine during a day, each single injection is a smaller dose. The smaller single dose does not lead to the same "high" that results from a larger dose. Perhaps the fact that Chris does not feel the euphoria when he receives the morphine is important in keeping him from being addicted. (It is acceptable for students to propose answers here even if they cannot be sure.)

- **Is a larger dose of a drug the only factor to consider when thinking about the causes of drug addiction? Explain your answer based on the case studies**.

No, because Chris took a larger dose and did not become addicted.

- **Is the length of time that someone has been taking drugs enough to determine if addiction will develop? Explain your answer based on the case studies**.

No, because Chris took morphine for a longer period of time and did not become addicted while Pat took morphine for a shorter period of time and did become addicted.

- **What factors other than the amount (dose) of the drug taken and the period of time for which the drug is taken may contribute to addiction?**

The expectation of feeling a "rush" may be a factor. A person getting morphine in a hospital would not be taking morphine just to get that feeling. The context of drug (medication) use influences whether a person becomes addicted. Pat's use of drugs to escape problems contributed to the development of drug addiction.

The cases should reveal to the students that just a high dose of a drug is not enough to cause addiction. The behaviors and motivations for taking drugs are important factors in the development of addiction. The street addict was using drugs with the expectation of a rush, or high, and trying to escape life. The patient was taking drugs without the expectation of a high. The patient experiencing pain uses drugs in order to function normally. Scientists do not completely understand why pain patients do not become addicted after drug use, but the statistics clearly show that these individuals are at very low risk of becoming addicted.

You may also want to discuss the case of Vietnam veterans with students. For many years, the media portrayed Vietnam veterans as hopeless drug addicts. Although drug addiction was a problem for some men while in Vietnam, the vast majority of those veterans have had no problems with drug addiction since returning to the United States. They may have started using drugs (and subsequently became addicted) to relieve the stress of combat, to rebel against society, or even to relieve boredom, but once they were back in a "normal" environment, they were able to function without drugs.

Content Standard A: Scientists rely on technology to enhance the gathering and manipulation of data.

ACTIVITY 5: LONG-TERM EFFECTS OF DRUG ABUSE AND ADDICTION

Having students view the CD-ROM mini-documentary on the long-term effects of drugs on the brain is the strongly preferred approach for this activity. If computers with a CD-ROM drive are not available, follow the procedure for the alternate version of the activity (provided on page 95).

1. **Have students view the mini-documentary, *Long-Term Effects of Drugs on the Brain,* on the CD-ROM.**

To view the mini-documentary, load the CD-ROM onto the computers. From the main menu, select *Drug Abuse and Addiction*.

2. **After viewing the CD-ROM segment, ask students to write their answers briefly to the following questions.**

   - **What was the most surprising thing you learned about the effect of drugs?**

- **What makes this fact surprising to you?**
- **Based on what you have learned through the rat experiment analysis, the card game, and the mini-documentary, would you say that drug addiction is a disease? Justify your answer.**

Students should be encouraged to relate what they learned in Activities 1 through 4 to what they learned from the mini-documentary.

Having students write their answers to the questions encourages them to organize their thoughts and reflect on what they have learned. Listening to students explain their view about drug addiction as a disease will help you evaluate their understanding.

3. After students have completed their answers to the questions, discuss the questions as a class.

Drug addiction is a disease that causes physical and functional changes in the brain. This is similar to other diseases in which a part of the body does not function properly.

4. Encourage students to learn about how drugs affect other body systems by doing library or Internet searches.

Because the focus of this unit is on the brain, the curriculum supplement does not address how drugs act on other parts of the body. However, a great deal of additional information is available online. See the section, *Additional References for Teachers*, for some informative Web sites.

ALTERNATE VERSION OF ACTIVITY 5 FOR CLASSES WITHOUT ACCESS TO COMPUTERS

1. Give each student a copy of Master 4.6. Instruct students to read the handout *Long-term Effects of Drugs on the Brain* and answer the questions.

After students finish reading and answering the questions, discuss the responses as a class.

SAMPLE ANSWERS TO QUESTIONS ON MASTER 4.6

Question 1. What are some of the ways that drugs cause long-term changes in the brain?

The continued use of drugs may cause the brain to become resistant to the effects of the drug (tolerance). Some drugs, such as alcohol and MDMA, can kill brain cells. Cocaine and amphetamine can cause the activity level of the brain to decrease for a long period of time after drug use is stopped.

Question 2. How does the brain adapt to the presence of drugs?

The brain adapts to the presence of drugs by developing tolerance for the drug and by the development of cravings if drug use is stopped.

Question 3. How may the abuse of drugs relate to the plasticity of the brain?

Plasticity means that the brain can modify connections (synapses) in response to experiences. Drugs that cause neuron death can decrease the plasticity of the brain because neurons are not present to form new connections and because existing connections are lost.

Question 4. What are some problems that scientists have when they investigate the effects of drugs on the brain?

Scientists have difficulty investigating the effects of drugs on the brain because many drug abusers abuse more than one drug. Scientists must understand how each drug affects the brain and body because drugs taken in combination may have different effects. Also, many drug abusers have other medical conditions that make it difficult for scientists to determine what effects are due to the drug and what effects are due to the other medical problem.

2. **If students want to learn more about how drugs affect other parts of the body, encourage them to do library or Internet searches for additional information.**

   Because the focus of this unit is on the brain, the curriculum supplement does not address how drugs act on other parts of the body. A great deal of information is available online. See the section, *Additional References for Teachers*, for some informative Web sites.